

“That Journal has a History”: Overview of the Technological Tools and Theories Studied in the *International Journal for Technology in Mathematics Education*, 2004-2018

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This paper constructs an overview of the historical development of the International Journal for Technology in Mathematics Education (IJTME) during the period 2004-2018. The titles of the published papers in this period are examined, focusing on what technological tools were studied, and what theoretical ideas were used to study the teaching and learning of mathematics with technology. This analysis shows the ways in which the IJTME has particularly focused on how students use, or can be helped to use, technological tools (mainly CAS, dynamic geometry software and calculators), as opposed to other possible topics such as historical analysis, policy, or international comparisons in the teaching and learning of mathematics with technology. The areas of mathematics primarily addressed by the articles are algebra and geometry, informed by the development of certain theoretical ideas (from instrumentation theory to activity theory for example) over the last 15 years. While the journal should keep investigating this area of research, it is also essential to extend the journal's scope to wider perspectives including sustainability of historical developments of technological tools, book review, systematic literature review, dialogues between our community members through commentaries on the published papers, and so on.

1 INTRODUCTION

The *International Journal for Technology in Mathematics Education* (IJTME) originally started as *International Derive Journal* in 1994, and then in 1997 changed its name to *The International Journal of Computer Algebra in Mathematics Education*, publishing articles about the use of computer algebra systems. After 10 years of leadership under the editorship of John Berry (University of Plymouth, UK), the journal re-launched under its current name IJTME, and has been providing a medium for a wide range of experiences in the use of new technologies in mathematics education. Ted Graham (University of Plymouth, UK), who took over as editor from Berry at the time of the re-launch, wrote in the first editorial in 2004 as follows:

The title of the journal has been changed to broaden the scope of the journal. While articles on the use of computer algebra systems will continue to be a key component of the journal's content, it hoped to encourage

more papers on the use of other technologies. In particular papers on other mathematical computer applications and also hand held technology, such as graphics calculators will be encouraged. The change in title has been as a response to the number of papers that have been submitted to the journal that could not strictly be described as computer algebra.

Since this change in direction, the IJTME has published 287 papers, and these papers indeed cover the use of a wide range of educational technologies in mathematics education. The articles are either research papers, ideas for teaching or discussion papers. The journal has also occasionally published Special Issues (SI), edited by conference organisers (e.g. SI for ICTMT-7, IJTME vol. 13 no.1-4 edited by Keith Jones and Federica Olivero, SI for ACA'2009, IJTME vol. 17 no. 2 edited by Kathleen Pineau, Michael Wester, France Caron, and Daniel Jarvis etc.).

In 2018, I took over the editorial role from Ted Graham. Since I have taken this exciting but challenging role, I have always wanted to explore the journal's history (my PhD study was about the history of the teaching of geometry in the early 20th Century, so why not?). This paper is my first attempt at this exploration, aiming at providing a comprehensive account of the historical development of the IJTME since 2004, in particular by taking an overview of the titles of the papers published in the IJTME between 2004 and 2018.

2 WHY HISTORICAL REFLECTION AND WHAT TO REFLECT ON

My original motivation to conduct a historical reflection of the IJTME stems from the famous words by H. E. Carr (1990) that history is “an unending dialogue between the past and the present” (p. 50), and my intention is to identify what has been done, and what will be needed for a future development of the journal and research in mathematics education with technology through dialogues with the historical development of the IJTME. This approach I believe echoes ‘Dig where you stand’, the motto of the international conference on the History of Mathematics Education.

Of course, it is necessary to clarify what kind of ‘dialogue’ is needed. Drijver (2015) pointed out the following three factors for successful integration of technology in mathematics education (pp. 147-8):

- Design: This concerns not only the design of the digital technology involved, but also the design of corresponding tasks and activities.
- Teacher: the teacher has to orchestrate learning, for example by synthesizing the results of technology-rich activities, highlighting fruitful tool techniques, and relating the experiences within the technological environment to paper-and-pencil skills or to other mathematical activities.
- Educational context: how important it is that the use of digital technology is embedded in an educational context that is coherent and in which the work with technology is integrated in a natural way.

Reflecting on the above factors, it is interesting to investigate questions such as ‘what tools have been studied in the IJTME’, or ‘what teaching approaches have been reported’. Ruthven (2008) stated many technological tools faded away in the past (e.g. Logo) and some did not (e.g. squared paper, which would no longer be seen as a ‘technology’ but would have been when it was introduced). A useful question is whether such trends can be observed in the articles in IJTME.

In addition to the above factors, as the IJTME is a research journal, it is essential to explore what theories and methodologies have been used in the journal. For example, questions could asked such as ‘when particular theories, such as instrumentation theory, appeared, and how were such theories developed in the journal?’ or ‘what methodologies have been used?’

Of these many interesting questions, during this first phase of my historical reflection, I would like to have a dialogue with the IJTME in terms of ‘tools’ and ‘theories’ around the use of these tools. It is almost impossible to make a perfect definition of ‘what is a tool in mathematics education’ (see, for example, Monaghan et al, 2016), but simply, for the purposes of this paper, technological tools are digital/non-digital artefacts for the teaching and learning mathematics such as graphic calculators, dynamic geometry software, etc. Equally, although ‘what is a theory’ is still a debatable question, ‘theories’ in this paper are theoretical ideas such as instrumentations, activity theory, etc. My (pragmatic) rationale of this choice of two themes is a) technological tools play an important role in teaching and learning mathematics (ibids.), and b) theories also play an important role to understand, describe and explain ‘multi-faced’ phenomena in the teaching and learning of mathematics (Bikner-Ahsbahs and Prediger, 2010) with technological tools.

3 METHODOLOGICAL APPROACH

The volume of papers published in the IJTME since 2004 render it impossible to review them all in detail. Grant et al (2009) suggest there are at least 14 types of review, and identifies one as an ‘overview’ – a summary of the literature that attempts to survey the literature and describe its characteristics (p. 94). The potential strength of this approach is, “Overviews can provide a broad and often comprehensive summation of a topic area and, as such, have value for those coming to a subject for the first time.” (p. 99) and hence I have chosen this methodology for this first attempt at a historical reflection of the IJTME. I construct my overview of the IJTME between 2004 and 2018 by examining the titles of the papers published, by focusing on the tools and theories in these papers.

I have taken an explorative approach to my historical dialogue with the IJTME. First, I accessed the educational database Ebsco Education Database (<http://eds.b.ebscohost.com>), which has indexed all issues of the IJTME between 2004 and 2018. I then downloaded the text data of the journal (e.g. title, authors, volume and issues, abstract, etc.), and extracted the titles (about 3200 words) and created text data by using a statistical software *R* and a text mining package (‘tm’). I decided to examine the titles mainly. Although titles do not always specify the technological focus of the paper (for example, the paper ‘Visualizing and Understanding Regression and Correlation Using Dynamic Software’ in 2018 does not specify that the software being studied is MS Excel), the titles do represent what the authors really want to tell readers about their papers and thus contain the ‘voice’ of the authors. I then examined the frequency of word use and when terminology such as GeoGebra started to appear in the IJTME, and so on. In particular, I examined what words related to tools and theories were most frequently used in various periods (this is presented in the next section). Also, where necessary, I accessed the papers and their abstracts and examined the contents of these papers to check what tools or theories were discussed in these papers.

4 TOOLS AND THEORIES IN THE IJTME BETWEEN 2004 AND 2018

4.1. What technological tools were studied in 2004-2018?

Between 2004-2018, 287 papers (excluding editorials) have been published, with an average 19.1 papers in each year (2018 is up to issue no. 3). This information is summarised in Table 1.

2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Vol. 11	Vol. 12	Vol. 13	Vol. 14	Vol. 15	Vol. 16	Vol. 17	Vol. 18	Vol. 19	Vol. 20	Vol. 21	Vol. 22	Vol. 23	Vol. 24	Vol. 25
16	16	23	24	15	15	29	27	16	20	13	23	14	26	10

Table 1 The numbers of the published papers in the IJTME.

'technology' as they are too general for the purpose of the review. Finally, 'calculator' and 'calculators' are replaced as 'calculator', similarly 'systems/system', 'teachers/teacher' and 'students/student' are unified).

student	using	teacher	learning	teaching	computer	use	algebra	cas	education
45	45	44	41	40	40	37	36	30	27
geometry	system	dynamic	software	based	school	calculator	geogebra	study	modelling
25	25	23	22	21	18	16	15	14	13
pre	service	activity	analysis	integration	classroom	case	assessment	tool	theory
12	12	12	12	11	10	10	10	10	10

Table 2 The most frequent words in the title of the papers published in the IJTME.

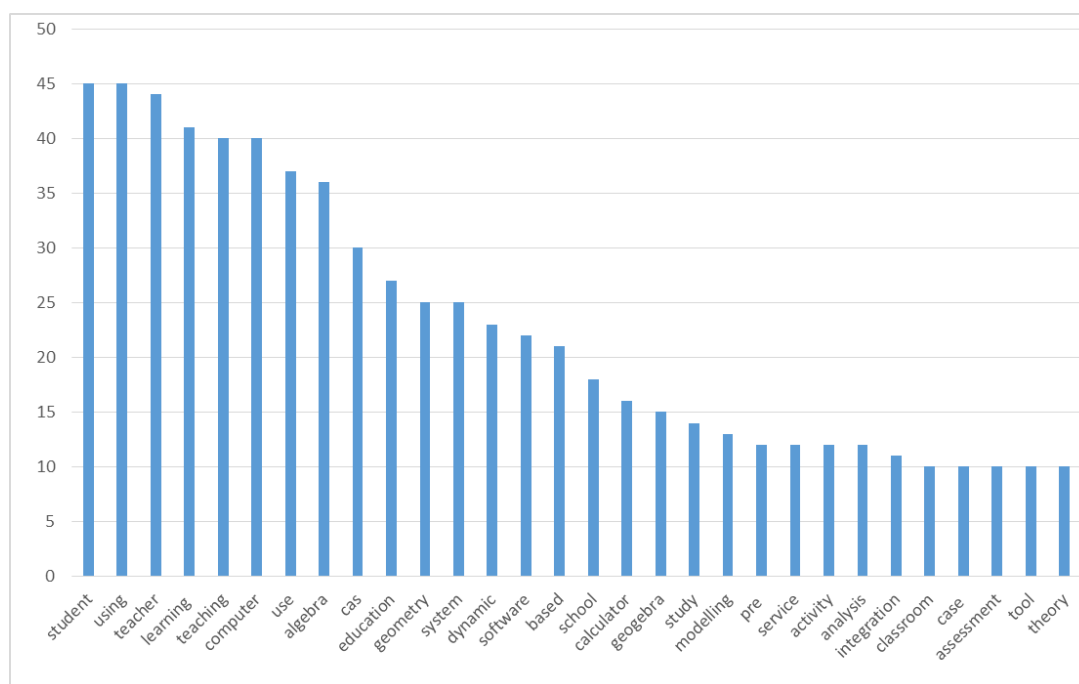


Figure 1 The most frequent words in the IJTME.

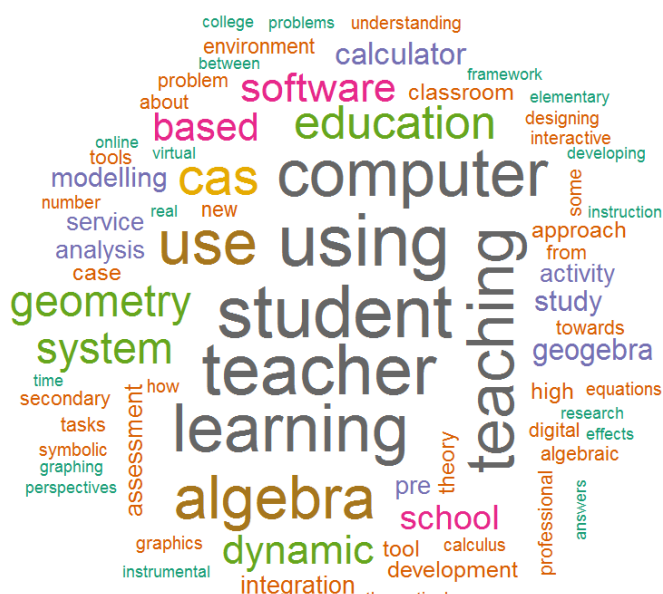


Figure 2 A wordcloud based on the titles from 2004-2018.

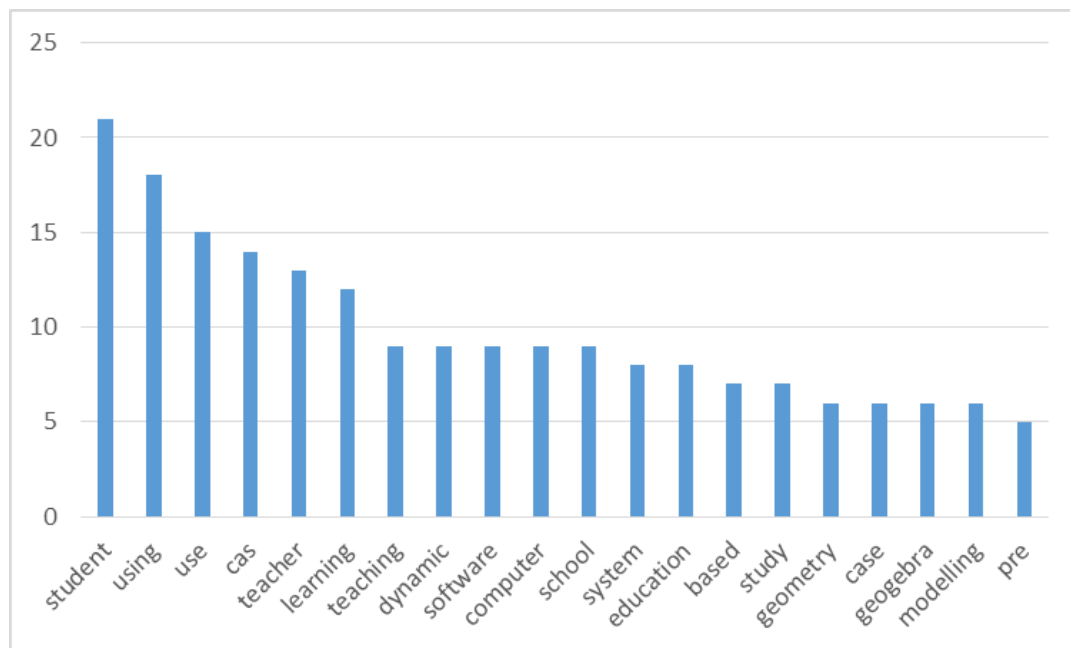


Figure 7 The most frequent words in the IJME in 2014-2018.

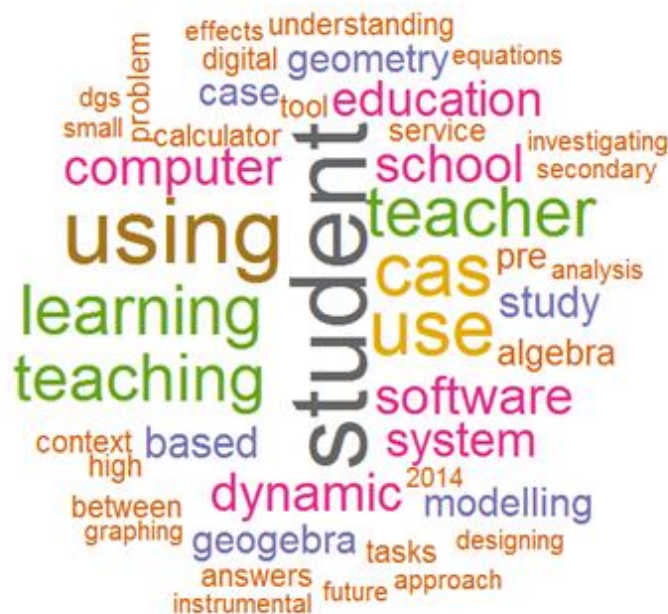


Figure 8 A wordcloud based on the titles from 2014-2018.

Figures 3, 5 and 7 illustrate the most frequently-used words in the titles within each of the three periods (20 words) as well as the wordclouds (Figures 4, 6 and 8). From these figures, several points of interest can be observed:

- **In 2004-2008 ‘algebra’ and ‘computer’ appeared frequently (Figure 3).** The papers were mainly related to computer algebraic system at that time (e.g. ‘Projects Using a Computer Algebra System in First-year Undergraduate Mathematics’ by Rosenzweig (Vol. 14 no. 3), ‘A Study of the Use of a Handheld Computer Algebra System in Discrete Mathematics’ by Allison and Grassl

(Vol. 12 no. 3), ‘Learning Algebra in a Computer Algebra Environment’ by Drijvers (Vol. 11 no. 3) etc.). Considering 94 papers were published in this period, at least 20% (and most likely more) papers were related to the use of computer algebra system at that time. Note the journal just changed its name in 2004 from *International Journal of Computer Algebra in Mathematics Education*. From Figures 5 and 7, the word ‘algebra’ is used less in the other periods (10 times in 2009-2013 and 5 times in 2014-18), indicating the journal’s interests and topics were moved to wider range of different technologies in mathematics education.

- **The word , ‘student’, ‘using/use’, ‘teaching’, ‘learning’, or ‘teacher’ are always frequently used in the three sub-periods (Figures 3 to 8).** More ‘students’ appear in 2014-18 (Figure 7), which might indicate that researching into the use of technological tools for students’ learning is one of the major concerns in the last 5 year of studies (e.g. ‘The Effect of Using Dynamic Mathematics Software: Cross Section and Visualization’ by Kōsa (Vol. 23 no. 4), ‘Using Online Professional Learning Communities to Encourage Dialogue in University/College Mathematics’ by Bond (Vol. 23 no. 2).
- **Algebra and geometry are the main mathematical topics (Figures 3-8).** The word ‘algebra’ is used the most frequently in 2004-18 but recently it seems more papers were related to geometry (of course, for example, the word ‘algebra’ in CAS is just a convenient word. In the early systems (on old computers with print-outs), CAS were algebra-symbolic. This, of course, remains with much CAS use today but in the 1990s the focus of some of the CAS-education work was co-ordinate ‘geometry’ (personal communication with John Monaghan). Calculus is another popular topic although only six papers used the word ‘calculus’ in their paper. However, other important areas of mathematical study like statistics and probability do not feature on the most commonly-used list, and have substantially less attention. In particular, no papers reported on dynamic representation tools such as *Tinkerplots* (Konold and Miller, 2011).
- **Dynamic geometry software first appeared in the journal in 2006 (Figure 3),** e.g. ‘Exploring Necessary and Sufficient Conditions in Dynamic geometry Environments’ and ‘Researching With Software - CAS, DGS and Cabri 3D’ by Oldknow (Vol. 13 no. 1), but the word ‘GeoGebra’ first appeared in the IJTME in 2009, including Hohenwater’s paper ‘Linking Geometry, Algebra, and Mathematics Teachers: GeoGebra Software and the Establishment of the International GeoGebra Institute’.

Although CAS (in particular during 2004-2008, see Figure 3), dynamic geometry software (e.g. GeoGebra, after 2009) and calculators seemed the most popular tools, the IJTME, as Graham wrote in the editorial in 2004, has been encouraging authors to study a range of different technological tools. For example:

- **Virtual reality learning environments** (at least 5 papers), e.g. ‘Teaching with Virtual Reality calculator Crafting a Lesson and Student Response’ by Goehle (Vol. 25 no. 1), ‘Using Virtual Manipulatives with Pre-service Mathematics Teachers to Create Representational Models’ by Westenskow and Moyer (Vol. 23 no. 2).
- **Online resources** (at least nine papers), e.g. ‘Pre-Service Mathematics Teachers’ Use of Web Resources’ by Caniglia and Meadows (Vol. 25 no. 3), ‘Design And Use Online Platforms To Learn Mathematics And The Use Of Them In Simulations Of Problems In Applied Sciences’ by Méndez-Fragoso et al (Vol. 24 no. 2), ‘High School

Students’ Acquisition of Knowledge and Skills through Web-Based Collaboration’ by Kunvits and Kunvits (Vol. 20 no. 3), ‘The Effects of Feedback on Online Quizzes’ by Butler et al (Vol. 15 no. 4), ‘An Assessment of Web-Based Homework in the Teaching of College Algebra’ by Mahmoud and Walsh (Vol. 14 no. 4).

In contrast, no paper titles include the word related to the tools such as ‘augmented reality’ or *Tinkerplots*. Also only two papers discussed digital or E-textbooks (‘Using Technology for Digital Mathematics Textbooks calculator More than the Sum of the Parts’ in 2017 and ‘The Future of E-Textbooks’ in 2015), and just one paper focused on multi-touch based technology (e.g. ‘What to use for mathematics in high school calculator PC, tablet or graphing calculator?’ in 2015). Of course, this observation is mainly based on the titles of the papers, and it would definitely be necessary to conduct a more thorough review of the papers. I return to this point in the latter part of this paper.

4.2. What theoretical ideas were used in the IJTME papers?

The word ‘theory’ is used explicitly 10 times in the titles (Table 2). From the titles of the paper alone, it is often, of course, very difficult to identify what theoretical ideas were used in the published papers in the IJTME. However, from a careful examination of the word frequencies and wordclouds of words appearing in the titles, the terms ‘activity’ (in 2009-13 wordcloud, Figure 6), ‘instrumentation (in 2004-08 wordcloud, Figure 4) or ‘instrumental’ (in 2014-18 wordcloud, Figure 8) are noticeable.

The ‘instrumentation theory’ approach is perhaps one of the main theoretical ideas for studying ‘the use of tools’ in the teaching and learning of mathematics. ‘Instruments’ are different from ‘artefacts’, and in this process ‘instrumental genesis’ is involved which is summarised by, for example, Drijvers, et al (2010) as follows:

The use of a technological tool involves a process of instrumental genesis, during which the object or artefact is turned into an instrument. This instrument is a psychological construct, which combines the artefact and the schemes (in the sense of Vergnaud, 1996) the user develops to use it for specific types of tasks. In such instrumentation schemes, technical knowledge about the artefact and domain-specific knowledge (in this case, mathematical knowledge) are intertwined. Instrumental genesis, therefore, is essentially the co-emergence of schemes and techniques for using the artefact. (p. 214)

This approach often appears in the recent papers in the IJTME, e.g. ‘Redesigning Task Sequences to Support Instrumental Genesis in the Use of Movable Points and Slider Bars’ by Fahlgren in 2017 or ‘Designing Spatial Visualisation Tasks for Middle School Students with a 3D Modelling Software calculator: An Instrumental Approach’ by Turgut and Uygan in 2015, but in the IJTME, the word ‘instrument’ first appeared in 2005 in the paper ‘The Didactical Challenge of Symbolic Calculators: Turning a Computational Device

into a Mathematical Instrument' by Monaghan. This paper was a book review – and the title of this paper was actually the book by Guin, Ruthven and Trouche Springer, 2005 (ISBN 0-387-23158-7). This book review is really worth reading for many reasons as it provides an overall picture of the instrumentation approach, terminologies used, and relationships with other theoretical ideas such as Chevallard's anthropological approach. These ideas are highly useful for studying the use of tools in the teaching and learning of mathematics, including analysis both of how tools are used, and how students can be helped to use them better. As shown in the previous section of this paper, such analysis is one of the IJTME's main concerns.

It is noticeable that Monaghan then wrote the paper 'Computer Algebra, Instrumentation and the Anthropological Approach' in Vol. 14 no. 2 (2007) in which he discussed the relationships and tensions between the instrumentation and anthropological approaches in CAS. This same issue of the IJTME also included a paper in which Blume reacted to the paper by Monaghan ('Reflections on John Monaghan's "Computer Algebra, Instrumentation, and the Anthropological Approach"'). The IJTME was founded to serve and nurture a community of researchers who are devoted to the study of technology in the teaching and learning of mathematics, and this community continues to thrive as each issue of the IJTME is heavily supported by the peer review in the community. It is particularly pleasing to see cases such as the Monaghan/Blume one, where the dialogue between the community members was 'explicit' in the journal, and the editorial board really encourages current community members to engage more in this kind of peer review and interaction.

The word 'activity' might imply students' activities for learning but it can also imply 'activity theory'. In fact, the word 'activity' is associated in the IJTME papers with 'theory' and 'theoretical'. Around six years ago, the IJTME provided two consecutive SIs with 14 papers (Vol. 19 no. 4 in 2012 and Vol. 20 no. 1 in 2013) devoted to this theory through publishing revised papers presented in ATATEMLO (Activity Theory approaches to technology-enhanced mathematics learning orchestration) in 2011, edited by Vandebrouck, Chiappini, Jaworski, Lagrange, Monaghan and Psychari. In these SIs, activity theory is introduced as follows: "Activity Theory (AT) is a philosophical and cross-disciplinary theory adopted for studying various forms of human practices, such as teaching/learning, that are seen as developmental processes mediated by artefacts, where individual and social levels are simultaneously interlinked (Kuuti, 1996)" (Vol. 19, no. 4, editorial). These papers, obviously, used 'activity theory' approaches but the second of the SI volumes, issue Vol. 20, no. 1 includes papers which discussed related theories. These include "the developments of Activity Theory by the French school, including Rabardel's perspective of instrumental genesis", semiotic mediation ('Semiotic Mediation within an AT Frame' by Mirko and Mariotti) and anthropological approach ('Anthropological Approach and Activity Theory: Culture, Communities and Institutions' by Lagrange). A commentary article by Stephan Lerman was also included ('Technology, Mathematics and Activity Theory', Vol. 20 no. 1). While a thorough review of the papers in these SIs is still necessary, at a glance it is very nice to see that the IJTME

provided a medium for expanding the theoretical ideas discussed in mathematical education. While research through the 'instrumentation' theory lens was perhaps most prevalent in the period 2004-2008 within the IJTME, these two SIs gave more of a platform for Activity theory framework in the 2010s, which perhaps brought this theory to a wider audience within our readership.

Of course, there are many other theories (or frameworks) used and discussed in the IJTME which do not explicitly appear in the titles. Some of them are quite broad and others are topic/domain-specific, e.g. Technological Pedagogical Content. Knowledge (TPACK) (Koehler & Mishra, 2005), pedagogical approaches with GeoGebra (Lavicza et al, 2010), procept (Gray and Tall, 1994), van Hiele's model (1999, but the original idea was proposed in the 1950s), Valsiner's (1987) zone theory, Hypothetical learning trajectory (Simon, 1995), dragging modalities (Arzarello, et al 2002), variation theory (Marton and Booth) and more. To make a thorough overview of all these theories would be a separate task, but it is again very nice to see the IJTME received papers from many different theoretical ideas in mathematics education with technology. Also, the journal welcomes papers which challenge or modify existing theoretical ideas. For example, a very recent paper by Honey (2018) has suggested TPACK+ as a way in which beliefs and attitudes can be taken into account in teachers' knowledge with technology. However, other ideas such as feedback with technologies are studied less (e.g. only two papers explicitly used the words 'feedback' in 2004-18), which has been recognised as one of the important issues in the teaching and learning of mathematics with technology (see, e.g. Hattie and Timperley, 2007; Fujita et al., 2018).

5 SO WHAT CAN BE LEARNT FROM THIS REFLECTION?

The IJTME is an international journal aimed at discussing the use of technologies in mathematics education, and its history is insightful. In this paper, I explored its history by taking an overview of the titles of the papers published over the last 15 years, focusing on the technological tools and theoretical ideas. Certainly there is a risk with only looking at the titles of the papers (and I am not claiming this paper is *the* history of the IJTME). My tentative conclusion is that the IJTME has particularly focused on the students' use of technological tools (mainly CAS, dynamic geometry software and calculators) in mainly algebra and geometry, and has provided a platform for certain significant theoretical ideas (e.g. instrumentation theory and activity theory) over the last 15 years. As an editor, I would like to keep this direction of the IJTME in the future, and hope to publish many papers which are grounded in solid theoretical ideas and research methodologies. Also, one of the strengths of the IJTME is that the journal publishes papers which report innovative use of technologies (under the theme, 'Ideas for teaching'). I did not explore the Ideas for teaching papers much in this paper, but papers in this category are always welcome.

As Carr suggested, an historical dialogue is unending, and there are many (indeed too many) questions which should be

asked about the last 15 years of the IJTME. For example, with the opportunity to study the published papers more thoroughly, one could choose to investigate what technological tools disappeared in the past and why, or why CAS and GeoGebra became such popular tools? Ruthven (2008) suggested the following four factors for success of technological tools (p. 98):

- Disciplinary congruence with an influential contemporary trend in scholarly mathematics.
- External currency in wider mathematical practice beyond the school.
- Adoptive facility in terms of ease of incorporation into existing classroom practice.
- Educational advantage through perceived benefits of use considerably outweighing costs and concerns

It would be interesting to use the above framework to investigate possible reasons why some tools disappeared in the past, and I particularly welcome such studies to be published in the IJTME.

I also did not focus on the research methodologies employed in the research papers at all. For example, what methodological approaches have been particularly used in the study of students' use of technological tools, what methodological challenges can be identified, etc. Such historical reflections enrich our understanding of the IJTME's strengths and weaknesses.

One final observation I make is that the IJTME has published relatively few review papers. However, among those that have appeared, it was really nice to discover, for example, Monaghan's book review in 2005, or 'Review of Paul Drijvers' PhD Thesis calculator Learning algebra in a computer algebra environment' in Vol. 11 no. 3 and so on, where the authors really engaged in dialogues in their papers of the IJTME. Also in 2010 can be found a paper 'Integrating Computer Algebra Systems in Post-Secondary Mathematics Education: Preliminary Results of a Literature Review' by Buteau et al. (Vol. 17 no. 2). Perhaps more papers are needed which undertake systematic literature review of the current developments in this field as well as book reviews, and, again, I hope the journal will receive more such papers in the future.

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BIOGRAPHICAL NOTES

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